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Inspection Testing of
Circuit Packages

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DISCLOSURE TEXT:

- A technique is described whereby limitations of laser photoemission testing of wiring are removed by contacting and properly biasing the wiring to be tested. By contacting and biasing the wiring, using techniques such as metal-clad flexible sheeting, problems associated with wire charging and materials variations are removed, for laser photoemission inspection testing of the wired packages.

- Contactless laser testing, for testing of logic states and switching transient waveforms on high speed semiconductor chips, has proved to be quite feasible. A critical application in packaging is the inspection of wiring for shorts and opens as well as for imperfections which may lead to shorts or opens during the functional operation of the circuit package. The concept

described herein

extends the laser testing to carry out this type of inspection in

both single- point scanning and in full-chip modes of operation.

- The concept takes advantage of the fact that the photoelectron threshold energy for exciting emission from the metal wiring,

typically 4 to 5 eV, is considerably below that for causing emission

from the surrounding insulating material of the package. For

example, Al_2O_3 has a band gap of 7.3 eV, so the threshold must be at

least this large and polymer materials should be similar. With laser

photon energies just above the threshold for the metal but below that

of the insulator, high contrast inspection testing by laser-induced

photoelectron emission can be expected. ***** SEE ORIGINAL DOCUMENT

The band alignments for such an ideal situation in the

insulating material of the package is depicted in Fig. 1(a).

With a perfect host material, the Fermi level E_F would be at the middle of

the energy gap E_G which separates the valence band maximum E_{val} and

the conduction band minimum E_{cond} . The level for vacuum emission is

the vacuum level E_{vac} , which is normally just above E_{cond} . Since

the material is assumed ideal, there are no electronic states in the

energy gap, so the highest energy occupied electron states lie at

E_{val} , and the minimum energy required to raise electrons above E_{vac}

is the photoelectric threshold $E_{photo} = E_{vac} - E_{val}$. If any low

concentration of electrons were available within the band gap,

electron emission would be possible at threshold excitation energies

starting at $E_{\text{thermal}} = E_{\text{vac}} - E_F$, because the highest such occupied

electron states in the gap would be at E_F .

- There are two contrasting situations which limit this approach:

non-ideal band alignments due to defect states and ideal band

alignments with electronically isolated wiring. Defects and non-ideal

band alignment

Band alignment may be different either at the surface or in the

bulk of the insulating packaging material, as shown in Fig. 1(b).

Here, a sufficient concentration of defect states exist within the

band gap to shift the Fermi level away from its midgap position.

With enough defects, E_F moves toward and eventually to the energy

position of the defect level E_{defect} , and thermionic emission

threshold changes toward or to $E'_{\text{thermal}} = E_{\text{vac}} - E_{\text{defect}}$.

Furthermore, a new value of E'_{photo} develops which lies below the

energy of E_{photo} . Such defects may be intrinsic to the nature of

the insulating packaging material.

Defects are associated with non-stoichiometry accompanying typical growth processes, as the

oxygen deficiency which makes ZnO always n-type, or they may be due

to impurities in the bulk or on the surface. The change in band

alignment for real situations results in that some photoelectrons

from the defect states will be excited together with those from the

metal wiring, so that contrast between the metal and the insulator

will be reduced. The contrast degradation will depend on the height

of the defect density.

- Ideal band alignments with electrically isolated wiring. If a few defects exist, it is expected that band alignments not only follow the characteristics of Fig. 1(a), but the resistivity of the insulator should be extremely high. For an isolated metal line of capacitance C , removal of charge Q by photoelectron emission from the line will shift the potential of the line to a $V = Q/C$. If this potential is comparable to the kinetic energies of the photoelectrons being emitted, this charging will cause microfields around the emission point. The charge lines will tend to attract the low energy photoelectrons until no more electrons can escape. The signal is therefore turned off by the charging.

- In estimating the degree of charging expected, typical capacitances for wiring lines on the packages range from 1 fF (10-15) to 1 pF (10-12F). For a signal-to-noise ratio of 30, 103 electrons must be measured per inspection point. Assuming that all photoelectrons emitted are collected and utilized in the measurement process, this corresponds to +0.2 mV and +200 mV charging for 1 pF and a 1 fF capacitance lines, respectively. By the time enough points are measured for a real inspection of the physical integrity of the line, the charging of the line is very significant. For example, a 10 mm. line which is 25m in width inspected with 5m resolution requires 104 points to be inspected. This would yield voltage shifts due to charging which are very large compared to the photoelectron kinetic energies used. It would therefore be necessary

to discharge the lines many times during the inspection of the

package or else to wait for the lines to discharge.

- It is evident that both cases, real and ideal, will lead to problems with laser photoemission inspection testing of the package wiring; with significant defects present, the metal vs. insulator

contrast will be degraded, while with few or no defects the charging

problem will become evident. By contacting the wiring with a

controlled voltage supply, both problems can be overcome. In the

case of real insulators, the metal lines can be biased by several

volts to gain the desired contrast, independent of the insulator. In

the case of near-ideal insulators, such biasing will maintain the

potential of the metal lines without shifts due to charging. Also,

the lines can be biased an amount appropriate to achieve high

contrast/discrimination between photoelectrons emitted from the metal

lines and those from the insulator.

- The required biasing of the metal wires to be inspected can be

accomplished by contacting a large number of wires on the package at

sites away from the portion of the package to be tested. Since C4

and EC pads, as shown in Fig. 2, are accessible at each chip site and

most are interconnected from one site to another, the concept

proposes shorting all of the pads together on the package everywhere

but at the chip site being tested. This may be accomplished by

pressing a metal-clad flexible sheet, such as copper plated on

MYLAR*, against the package, where a portion of the sheet has been

cut out at the chip site to be tested. .

- In this way, all portions of the C4s and ECs at the site under test will reach voltage V_{bias} , except those few which do not contact either portions to another chip site, either directly or indirectly.

Once the sheet is attached and the biasing is accomplished, the surface wiring at site B can be inspected by the laser testing

technique. The measured photocurrents reflect the potential of the point addressed by the laser. Because the wires are electronically

connected to a voltage bias source, the measured potentials are not

affected by charging of the wire in the package or contrast

variations due to unknown photothresholds of the insulating material.

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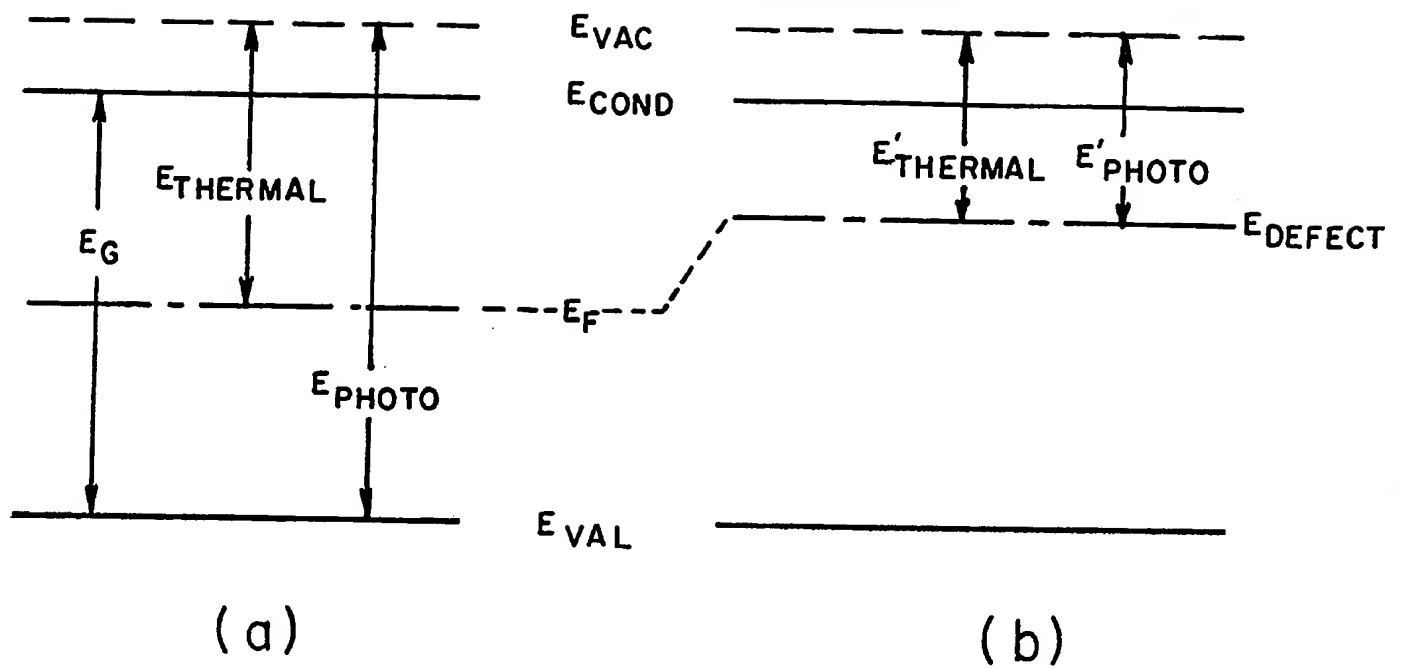


FIG. 1

